

Results of the Lunar Exploration Analysis Group (LEAG) GAP REVIEW Specific Action Team (SAT). Examination of Strategic Knowledge Gaps (SKGs) for Human Exploration of the Moon. C.K. Shearer¹, D. Epler², W. Farrell³, J. Gruener², S. Lawrence², N. Pellis⁴, P.D. Spudis⁵, J. Stopar⁵, R. Zeigler², C. Neal⁶, and B. Busey⁷. ¹University of New Mexico, Albuquerque, NM 98122. (cshearer@unm.edu), ²NASA-Johnson Space Center, Houston, TX 77058, ³NASA Goddard Space Flight Center, Greenbelt, MD 20771, ⁴Division of Space Life Science, USRA, Houston, TX 77058, ⁵Lunar and Planetary Institute, Houston TX 77058, ⁶University of Notre Dame, Notre Dame, IN 46556 ⁷NASA Headquarters, Washington DC 20546.

Introduction The Lunar Exploration Analysis Group (LEAG) was tasked by the Human Exploration Operations Mission Directorate (HEOMD) to establish a Specific Action Team (SAT) to review lunar Strategic Knowledge Gaps (SKGs) within the context of new lunar data and some specific human mission scenarios. Within this review, the SAT was to identify the SKGs that have been fully or partially retired, identify new SKGs resulting from new data and observations, and review quantitative descriptions of measurements that are required to fill knowledge gaps, the fidelity of the measurements needed, and if relevant, provide examples of existing instruments or potential missions capable of filling the SKGs.

Background The starting point of this analysis was the results of earlier analyses by Human Space Flight Architecture Team (HAT) and LEAG. SKGs for implementing the “Moon first” option had previously been defined by HAT and the LEAG GAP-SAT 1 (http://www.lpi.usra.edu/leag/GAP_SAT_03_09_12.pdf) and 2. The LEAG “GAP-SAT” 1 identified important SKG and placed them within the context of (1) enabling or enhancing components in the “Moon First” scenario, (2) the Planetary Science Decadal Survey, (3) the LEAG Lunar Exploration Roadmap (<http://www.lpi.usra.edu/leag/roadmap/>), and (4) NASA’s Human Space Flight Architecture Team’s (HAT) mission scenario development. LEAG GAP-SAT 2 provided a quantitative description of measurements that are required to fill knowledge gaps, identifying the fidelity of the measurements needed, and if relevant, providing examples of existing instruments capable of making the measurements.

Results The SKGs were placed within the context of three themes: I. Understanding the Lunar Resource Potential, II. Understanding the Lunar Environment and Its Effects on Human Life, and III. Understand How to Work and Live on the Lunar Surface. SKG categories under each theme were classified as retired, the measurements or mission needed to retire, and whether it enables or enhances human exploration of the Moon. Some of the SKGs retired from the results of past and current missions and Earth-based testing-observations include such categories as SKG I-A: *Solar illumination mapping*, SKG I-D-Polar Resources 1: *Extent of cold traps*, SKG I-D-Polar Resources 2:

Correlation of cold traps and permanent darkness, SKG II-C-1: *Earth-based testing of the Biological effects of lunar dust*, and SKG III-1: *Lunar mass concentration and distributions*.

There are numerous SKGs that have not been retired that are enhancing for short-duration missions (less than 28 days), but enabling for long-term sustained, human operations on the Moon. These SKG categories include (but not limited to): SKG I-C *Regolith 3: Preservation of volatile and organic components during robotic and human sampling, handling, storage, and curation*,

SKG I-D *Polar Resources 5: Charging and plasma environment within and near PSR*, SKG II-A-1: *Solar activity/solar event prediction*, SKG II-B-2: *Radiation environment at the lunar surface (measurements)*, and SKG III-D-1: *Lunar dust remediation*.

Findings This LEAG SAT finds that: (1) Recent missions (e.g. LRO, GRAIL, LADDIE) produced data to retire several of the SKGs defined by HAT and the 2011-2012 LEAG GAP-SAT analyses. (2) Thanks to these missions, there are no SKGs that would inhibit the flight of any human mission (e.g., sortie or human-tended surface facility) <28 days duration. (3) However, there are several SKGs that should be addressed that would increase human safety not only at the Moon, but also in LEO, cisLunar space, and beyond the Moon. This includes the development of infrastructure to monitor solar activity (e.g. solar storms). (4) In the context of a “Moon First Scenario” that develops assets and capabilities for human activity within the Earth-Moon system (EMS) and beyond EMS to near-Earth asteroids and Mars, there are numerous SKGs that would enable and enhance more mature human exploration capabilities for the Moon and beyond. (5) Future programmatic, competed (Discovery, New Frontiers) and international missions to the Moon should be examined for potential NASA contributions for retiring SKGs. This could take the form of contributed instruments to international missions and “credit” or contributed instruments toward NASA competed missions. (6) NASA programs such as Solar System Exploration Research Virtual Institute (SSERVI) should coordinate and encourage activities to retire SKGs.